Introductory Astronomy

Week 6: Relativity and Black Holes

Clip 12: Black Holes

Duke University

Gravitational Redshift

- Near Earth we found $\lambda = \lambda_0(1 + gH/c^2)$
- Away from Earth expect something like $gH \to \frac{-GM}{R}$
- In fact, observing from a great distance the correct expression is

$$\lambda = \frac{\lambda_0}{\sqrt{1 - \frac{2GM}{Rc^2}}} \sim \lambda_0(1 + \frac{GM}{Rc^2}) \quad R \gg R_S = \frac{GM}{c^2} \sim 9\,\mathrm{mm}$$

Duke UNIVERSITY

Horizons

- What happens if you can get near R_S ?
- Can you? $R_S = \left(\frac{M}{M_\odot}\right) 2.95\,\mathrm{km}$
- Neutron stars are close
- As you approach horizon redshift

$$\lambda = \frac{\lambda_0}{\sqrt{1 - R_S/R}} \rightarrow \infty$$

- Looking from afar you never get there
- Slow and dim as you near horizon – as seen from afar
- No light comes out!
- Distant light blueshifted as seen near horizon

Coming Closer

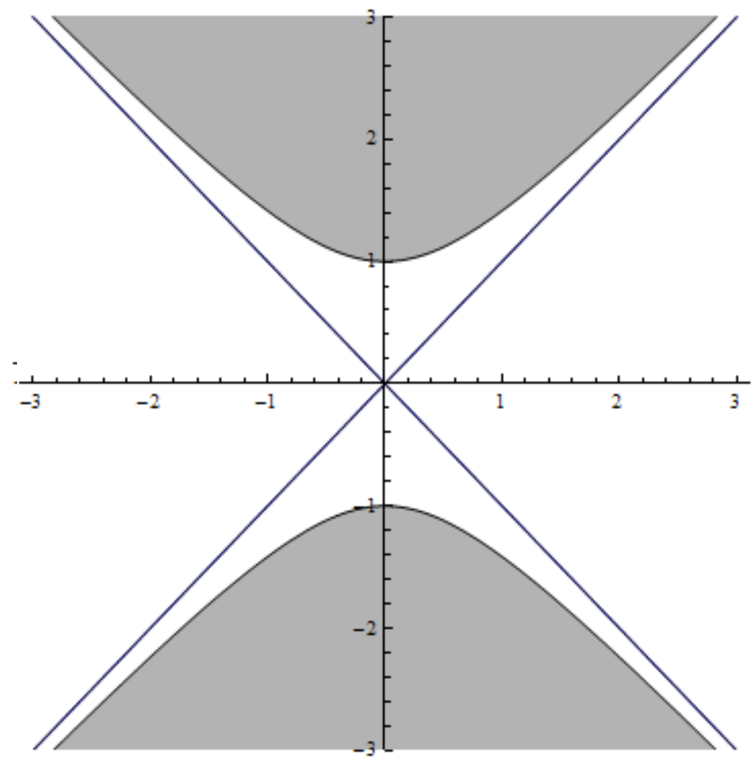
- If you can get to within a few R_S relativistic effects become marked
- Stable orbits exist for $R \geq 3R_S$ so nothing orbits nearer
- At $R = 1.5R_S$ light in unstable circular orbit

- Tidal forces can become extreme at small R
- However less so for large mass

$$\frac{2GMd}{R_S^3} = \frac{dc^6}{4G^2M^2}$$

Coordinate Issues

- At horizon time stands still – as seen from afar
- Use a better clock – free falling in
- Horizon is in fact lightlike
- Once inside even lightspeed will not get you out



Inside the Horizon

- What happens to the stellar core that collapsed?
- Once inside horizon, within finite proper time (measured by your clock) reach singularity
- At singularity tidal acceleration diverges so matter ripped apart
- Divergence signals breakdown of equations. We don't know.

Duke University

Credits

- Kruskal Coordinates: Wikimedia Commons/AllenMcC http://en.wikipedia.org/wiki/File:KruskalKoords.gif

Duke UNIVERSITY